Underinvestment in Public Good Technologies

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ABSTRACT. Although underinvestment phenomena are the rationale for government subsidization of research and development (R&D), the concept is poorly defined and its impact is seldom quantified. Conceptually, underinvestment in industrial R&D can take the form of either a wrong amount or a suboptimal composition of R&D investment. In both cases, R&D policy has not adequately modeled the relevant economic phenomena and thus is unable to characterize, explain, and measure the underinvestment. Four factors can cause systematic underinvestment in R&D-intensive industries: complexity, timing, existence of economies of scale and scope, and spillovers. The impacts of these factors vary in intensity over the typical technology life cycle, so government policy responses must be managed dynamically. In addition to understanding the causes of underinvestment in R&D, the magnitude of the deficiency relative to some "optimum" must be estimated to enable a ranking of technology areas with respect to expected net economic benefits from a government subsidy. Project selection criteria must therefore be based on quantitative and qualitative indicators that represent the nature and the magnitude of identified market failures. The major requirement for management of R&D policy therefore is a methodology that regularly assesses long-term expected benefits and risks from current and proposed R&D portfolios. To this end, a three-stage process is proposed to effectively carry out R&D policy analysis. The three stages are (1) identify and explain the causes of the underinvestment, (2) characterize and assess the investment trends and their impacts, and (3) estimate the magnitude of the underinvestment relative to a perceived optimum in terms of its cost to the economy. Only after all three stages of analysis have been completed can the underinvestment pattern be matched with the appropriate policy response.

Key words: R&D innovation, underinvestment, policy

JEL Classification: O3, O2

1. Introduction

Understanding the role of technology in economic growth requires the development and application of microeconomic theory. This is because each technology has unique characteristics, which interact iteratively over the technology's life cycle with unique industry structures and technical infrastructures. The microeconomic character of such an evolutionary model is further enhanced by the fact that the majority of technology investment decisions are made by individual companies and external financing is often supplied by individuals and small venture capital firms, with much of the financing for particular technologies limited to specific geographic regions.

Economists have explored the numerous elements of the microeconomics of technology-based growth, including the determinants of research and development (R&D) spending, project selection, the tradeoffs between R&D costs and time within a portfolio management context, the interactions of this activity with firm size and market structure, and the responses of R&D investment decisions to different financial and regulatory incentives. In addition, the results of such investments have been estimated using several analytical frameworks.

However, no one has surpassed Mansfield *et al.* (1968, 1971, 1982) in the number of these elements analyzed with respect to both investment and results, the level of disaggregation explored, and the collection and use of industry data to enlighten the proposed frameworks. Mansfield *et al.* (1977) have had a particularly pronounced effect on the analysis of the results of innovation. Their work in the late 1970s in which social and private rates of return were estimated for a range of R&D investments in manufacturing technologies followed Griliches' (1958) path breaking work in agriculture and collectively drew attention to the "gap" between social and private rates of return. This gap has spawned several decades of debate over

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government roles in supporting various amounts and types of R&D [including Mansfield *et al.*, (1982)]. Economists [including Mansfield, (1980, 1991a, b)] subsequently disaggregated R&D into basic research and applied R&D to examine the differences in rates of return between the "pure public good" (basic science) and the target of applied R&D ("proprietary technology").

Mansfield's broad and highly microeconomic analysis has provided an analytical platform for needed progress in assessing the implications of the "gap" for public policy. This paper focuses on barriers to R&D investment that result in suboptimal distributions of R&D investments across different types of R&D and thereby reduce potential long-term economic growth. The point of departure is the proposition that the gap between the social and private rates of return to R&D investments is not automatically an indicator of underinvestment and, at least as important, it is not an indicator only of potential underinvestment in the amount of R&D. Barriers arise that affect the composition of R&D and this class of market failures can have significant long-term negative effects on economic growth. The resulting added complexity to R&D policy analysis requires a more microeconomic approach in the Mansfield tradition.

2. R&D market failure analysis

Firms conduct R&D for two reasons: (1) to develop new products, services, or processes, and (2) to maintain a capability to identify and assimilate technologies from external sources (Cohen and Levinthal, 1989). Governments of industrialized nations obviously consider these activities to be essential for economic growth because they maintain various sets of R&D support policies. Yet, the theoretical and operational frameworks for managing such policies are incomplete.

Economists have consistently estimated the rates of return from R&D to be considerably above those obtainable from other assets. However, for R&D in aggregate, significant rate of return (RoR) differentials for social (industry) versus private (innovator) R&D investments have been found.[1] Moreover, among types of R&D, basic research and long-term, high-risk technology research have yielded particularly high rates of return (Griliches, 1995). The implication of these persistent rate-of-return differentials is the existence of systemic "market failure." However, the interpretation and policy implications of these RoR differentials are poorly defined because the majority of the economics literature has misspecified the knowledge production and innovation processes, resulting in inaccurate R&D policy prescriptions for dealing with the implied underinvestment.

Assessments of private sector underinvestment have been based largely on the neoclassical concept of externalities (Pigou, 1932) and defined as differences between actual investment patterns and an optimum rate of investment. However, this concept of market failure has not been made operational in the sense that specific roles for government can be deduced (Ruffin, 1996). Coase (1960, 1992) made a huge contribution toward resolving the problem by emphasizing that overcoming the difficulties in estimating the amount and nature of underinvestment mechanisms resulting from externalities requires the definition and then the assignment of property rights and associated transaction costs. The institutional (government) role therefore becomes extremely important and also case specific. Consequently, a microeconomic analysis of each specific case is required.

For R&D, analysis of market failure mechanisms and the consequent need for government intervention require accurate models of the unique set of factors determining this category of investment. If the needed models were straightforward, government R&D strategies would be relatively simple to design and manage. However, private investment incentives respond negatively to the public good content of technology and this content is distributed among elements of the typical industrial technology in more complex ways than generally realized. In particular, most industrial technologies (or, more accurately, elements of them) have a quasi-public good character, which complicates and thus inhibits addressing property rights issues, thereby substantially raising transaction costs, as originally identified by Coase.

Moreover, other factors besides property rights are important in determining R&D